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Occupant Behaviour and Evacuation

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ABSTRACT

Today most buildings are equipped with adequate fire safety systems. Nevertheless fires still occur, even fatal fires. During a fire, problems frequently arise because systems were put in place with false expectations regarding how occupants actually behave during fires. The observation that occupants tend to ignore the sound of the fire alarm in large public buildings such as shopping centres, museums or airports, continuing their normal activities should be taken into account. In office buildings, well designed fire doors have failed to fulfil their role because occupants have installed door stops to facilitate free movement in the everyday use of the building; thus in the event of a fire, the doors stay open. Many of these problems could be foreseen if more attention were given to human behaviour in fire. In addition, there are a number of other factors that could have an impact on occupant response and behaviour. These factors are related to the occupants' characteristics, the building characteristics and the fire characteristics. Consideration should be given to the interplay of these factors to gain a better understanding of human behaviour in fire and to improve the design and implementation of fire safety systems in buildings.

INTRODUCTION

The field of human behaviour in fire is fairly new compared to other areas of fire research. Although fires have killed people for centuries, destroying part or even whole cities, it is only recently that research into human behaviour in fire has started thriving. The 20th century has been marked with a new fire phenomenon: a single fire killing a large number of people. In North America, the Iroquois Theatre fire, the Coconut Grove Fire or the Beverly Hills supper club Fire have shocked the imagination of the public. Supported by dramatic media coverage these fires have become legendary for the inappropriate behaviour of the occupants, the inadequacy of the buildings in providing for a safe evacuation and the potential for such tragedies to happen again.

Studies in the field of human behaviour in fire started seriously in the 1960-70s with the work of Bryan in the United States and Canter, Sime, Breaux and Wood in the United Kingdom. Publication in 1980 of the book "Fires and Human Behaviour", edited by David Canter gave, at the time, a state of the art in this field, much of which is still applicable today. Research in this area slowed down

considerably in the mid-80s with the drastic reduction of funding for this kind of research in North America and Europe. After 10 years of struggle, research in this field has picked up again. The field is more dynamic than ever, with contributions from researchers located all around the planet as testified by the books of Proceedings from the 1st and 2nd International Symposium on Human Behaviour in Fire [1, 2]. Although this area of research appears extremely prolific, the work to be done is immense considering that research just started a few decades ago. Fascinating studies regarding response to fire cues, timing of escape, the impact of training, original wayfinding systems, etc. are among the few projects being conducted at the moment. A lot more is to come.

PANIC BEHAVIOUR

The first common expectation about human behaviour in fire that should be dealt with is the assumption that during a fire, occupants will panic. The possibility of panic behaviour in a fire is considered a "myth" by social scientists since the 70s as can be seen from publications from Sime [3], Keating [4] or Quarantelli [5]. Although the media are very fond of this concept for its drama and sensational connotation which makes good sales, there is little evidence of panic in actual fire situations. It is a widespread misconception to believe that people caught in a fire will panic and try to flee in a stampede, crushing and fighting others. Such crazed behaviours are in fact extremely rare. Panic which supposes irrational behaviour for a situation is rather atypical of human behaviour in fire. On the contrary, people appear to apply rational decision making in relation to their understanding of the situation at the time of the fire. In retrospect, it is easy to point to some decisions that were not optimal and played a negative part on the outcome of a fire, however, at the time of the fire these decisions were rational when all factors are considered.

It is commonly observed during interviews that victims themselves mention that they have panicked during the event. In a recent interview a victim said: "when I realised it was indeed a fire, I panicked. I ran to get the baby and left the house to go to the neighbour, leaving the main door open". The consequences of not closing the main door were that the fire growth and damage to the property were substantial. The public often use the word "panic" as synonymous for being frightened, scared, nervous or anxious; usually it does not have the implication of irrational behaviour. When analysing the behaviour of that occupant it cannot be concluded that this person panicked since the actions were perfectly rational for the situation, in relation with the information this person had at the time of the fire. The limited knowledge that people have on fire development and fire dynamic do not prepare them to have the best response during fires. A majority of people who are faced with a fire situation react in a rational fashion considering the ambiguity of the initial cues, their limited knowledge about fires and the restricted time they have to make a decision and to take action.

Contrary to common belief, it appears that it is the lack of panic that characterizes most fires. In the initial moments of a fire, upon smelling smoke or

hearing the fire alarm, it is often observed that occupants do not react, and deny or ignore the situation. This seems especially true in public buildings where occupants do not want to overreact to a false alarm or a situation that is already under control. Such avoidance or acceptance of a dangerous situation often results in delays in starting evacuation of a building or in taking protective action.

OCCUPANT BEHAVIOUR

If occupants do not panic in fires, what do they do? The occupant behaviour varies according to three major elements; a) the occupant characteristics, b) the building characteristics and c) the fire characteristics. These three elements interplay in the whole development and outcome of the event.

There are a number of factors that could simultaneously have an impact on occupant behaviour during a fire. The factors presented in Table 1 do not represent an exhaustive list. Furthermore, some factors may have a greater impact than others.

The occupant characteristics will be paramount in explaining and predicting potential occupant behaviour. This includes the occupants' profile which groups important parameters that can be influential in predicting their response to a fire, such as the occupants' age and mobility. Knowledge and experience of the occupant is also an important factor, since occupants who have or don't have training can react very differently. The condition of the person at the time of the event can also determine their potential to react promptly and appropriately. Personality and decision-making styles of each occupant can be influential; some copy the reactions of others, while others are prepared to take on a leadership role. Finally, the occupant's role in the building can explain different responses, for example, in a restaurant, the owner might be more likely to fight a kitchen fire than a client.

Among the building characteristics, a few types of occupancy have been identified in Table 1 to illustrate the importance of looking at the essence of each building and building areas. The traditional way to approach occupancy classification is sometimes too broad to support predictions relative to occupant behaviour in fire. For example, it cannot be expected that occupants in a church, a cinema or a skating rink will react the same way in the event of a fire even though these buildings are all assembly type occupancies. Each of these locations presents a specific problem. The architecture of the space is another important building characteristic. If the space is complex, it can have a major impact on occupant movement and on the possibility of finding an alternative way out if the familiar route is blocked. At the time of the fire, the activities happening in the building will have a major impact on occupants' response and reaction time. For example, in a hotel, whether the clients are in their rooms, at the swimming pool or on the casino floor, will have an impact on their reactions. Finally, the building fire safety features will also play a key role in informing the occupants of the situation.

Table1: Factors having an impact on Human Behaviour in Fire

Occupant Characteristics	Building Characteristics	Fire Characteristics
Profile • Gender • Age • Ability • Limitation	**Occupancy** • Residential (lowrise, midrise, highrise) • Office • Factory • Hospital • Hotel • Cinema • College and University • Shopping Centre	**Visual cues** • Flame • Smoke (colour, thickness) • Deflection of wall, ceiling, floor
Knowledge and Experience • Familiarity with the building • Past fire experience • Fire safety training • Other emergency training	**Architecture** • Number of floors • Floor area • Location of exits • Location of stairwells • Complexity of space/Wayfinding • Building shape • Visual access	**Olfactory cues** • Smell of burning • Acrid smell
Condition at the Time of Event • Alone vs. with others • Active vs. passive • Alert • Under Drug – Alcohol – Medication	**Activities in the Building** • Working • Sleeping • Eating • Shopping • Watching a show, a play, a film, etc.	**Audible cues** • Cracking • Broken glass • Object falling
Personality • Influenced by others • Leadership • Negative toward authority • Anxious	**Fire Safety Features** • Fire alarm signal (type, audibility, location, number of nuisance alarms) • Voice communication system • Fire safety plan • Trained staff • Refuge area	**Other cues** • Heat
Role • Visitor • Employee • Owner		

The fire characteristics can play an important role in the occupant response. During a fire, people perceive different cues from the fire and their interpretation of the situation will change rapidly, influencing their behaviour. Perceiving a smell of smoke will initiate a different response than directly seeing the fire.

The difficulty in attempting to predict the occupants' behaviour is that a number of the characteristics mentioned above are mixed in different patterns according to each situation. There are a few concepts, however, that can help explain and predict some of the occupant behaviour. The concept of commitment is one of them. For example, let's imagine people in a cinema watching a suspense movie. The fire alarm signal goes off, the sound level of the alarm is audible above the sound track and occupants recognize the signal. According to the objectives of the fire alarm signal, the signal should prompt immediate action and initiate evacuation movement. Unfortunately, these reactions are unlikely to happen. It can be expected that most occupants would stay in their seats hoping that the alarm signal will shut off soon. Such a response could be explained by the concept of commitment. Occupants who have paid good money to watch a trendy movie are not prepared to leave while they are engrossed in the story. They are committed to the activity of watching this movie and the fire alarm signal by itself is unlikely to be sufficient to make them leave. Being committed to an activity such as eating a meal, waiting in line for a ticket, watching a show, etc., is very powerful. People have a decision plan to carry out a specific activity and are reluctant to switch their attention to something unrelated.

As another example, the concept of role can explain the lack of response of some occupants in public buildings. In a museum or a department store, most occupants play the role of visitors and as such, they expect to be taken care of. If the fire alarm signal is activated, there are social interactions taking place: people will be looking at what others are doing. Therefore, if others are not paying attention to the fire alarm signal, occupants become reluctant to take any action that would make them appear out of place or over-reacting to an insignificant situation. The role of visitors is usually to conform to the general behaviour of others. Furthermore, visitors feel that it is their role to wait for instructions, even if they have recognized the signal as a fire alarm signal. They expect that someone will tell them what to do if something serious is really happening.

THE TIME TO START EVACUATION

Despite constant efforts to educate the public as to the meaning of the fire alarm signal, i.e., "fire alarm signal = leave immediately", this association is not automatic for every situation. For instance, in most public buildings, occupants' interpretation of the fire alarm signal is that something is happening, which is unlikely to be a fire, so we should stay put and wait to see what happens. Even with the perception of the smell of smoke or the sight of some smoke, occupants are reluctant to take any action on these ambiguous cues.

It is paramount to consider this time delay to start evacuation in assessing the risk to life in a building. Fire safety systems should be developed with this finding in mind: after fire ignition and detection, occupants will spend several seconds, if not minutes, in non-evacuation actions. Time will be spent investigating and finding information to interpret the perceived cue. Once occupants are pretty

sure that this is indeed a fire or an emergency, they are likely to engage in behaviour such as finding children, pets or even valuables before deciding to evacuate the building.

So far, the delay time to start has been studied in two ways: during evacuation drills and from fire victim interviews. Some tend to denigrate the fire drill studies although they are perfectly representative of a fire situation, especially if the drill is non-announced. Fire drills represent exactly the situation that would face occupants if the fire was located in a remote area or on an upper floor of the building and the only sign of fire would be the sudden sound of the fire alarm signal.

During evacuation drills, delay time to start was obtained for over 500 occupants in 7 multi-units residential buildings of 6 to 14 storeys in height [6]. For ethical reasons, occupants of these residential buildings received a note a few weeks before the exercise informing them that a fire drill would be conducted in their building without informing them on the date and time. Video cameras located in the building corridors recorded the exact time occupants took to leave their apartments. A questionnaire filled out after the drill provided essential information on occupants' perception of the fire alarm, their interpretation of the signal, their actions before leaving their apartment and their evacuation movement. Around 25% of the occupants in each building thought it was a real fire.

Significant variations were observed for the time to start evacuaton in the buildings studied. A clear distinction was made between buildings with a good or a poorly audible fire alarm signal [7]. From questionnaires, when over 80% of the respondents mentioned that the fire alarm was loud enough in their apartment, it was judged that the building had a good audible fire alarm signal. In the buildings where the alarm had good audibility, the mean delay time to start evacuation was around 3 min. In these buildings, three-quarters of the total evacuation time was due to the delay time in starting and one-quarter in movement time. The height of the building had little influence on the overall evacuation time.

In the 2 buildings where over 20% of the occupants judged that the alarm signal was not loud enough inside their unit, the mean time to start evacuation was around 9 min. These occupants took an extra long time to start since many started only 2 to 3 min after hearing the arriving fire trucks or after firefighters knocked at their door.

From the questionnaires, occupants mentioned that during their delay time to start they were doing actions such as: getting dressed, gathering children, pets, purse, wallet and keys. Some put away supper, had a look on their balcony or gave a call to the superintendent before leaving their apartment. Six of these evacuation drills were conducted in the summer on a weekday at around 19:30, the seventh evacuation was in the winter on a Saturday at 11:00. It is not known

what would be the delay time to start evacuation at night but it is likely to be longer than the times observed during the day. It is also interesting to know that in all these evacuation drills, many occupants (maybe as much as half the occupants present) never left the building and many refused to answer the firefighters who knocked at their door. This behaviour might be more prevalent at night.

Evacuation drills were also studied in 3 Canadian government office buildings [8]. Occupants received no warning of this exercise, since these Canadian government buildings conduct evacuation drills annually. Data on time to start was gathered using video cameras. The individual time to start of over 1000 occupants was recorded. The mean time to start evacuation for the 3 buildings was 50 s. Although all these office workers had received training and were fully aware of the evacuation procedure, they nevertheless spent time finishing phone calls, saving data on computers, securing files and gathering belongings before leaving their desk. Many had to be prompted to move by their local fire warden.

In their fascinating evacuation study of a large retail store, Shields, Boyce and Silcock [9] found that staff response had the most determinant effect on the occupant time to start their evacuation. They conducted an unannounced evacuation drill of a Marks & Spencer's store using video cameras to record behaviour and movement and a questionnaire administered to evacuees after the drill. The fire alarm was activated in the entire store. Although floor staff was not aware of the drill, their fast response was essential in prompting customers' movement. The average time to start moving for customers after the sound of the alarm was 25 s with a maximum of 55 s. Cash counters were closed within 30 s of the alarm sounding. Customers in the changing rooms were all evacuated by staff within 60 s. Clearly the fast staff response during this drill had a major impact on the fast evacuation of the store.

Time to start evacuation was studied in an underground transport system by Proulx and Sime [10]. This study demonstrated the importance of the cue received to prompt evacuation movement. In the underground levels of the station, passengers never started to evacuate after the activation of the fire alarm signal: they kept waiting for their train, reading, standing and never made a move to evacuate. When staff appeared to prompt movement, passengers complied immediately. The same response was observed with the use of precise live messages from the voice communication system. The messages informed the passengers of the type of incident, its location and instructed them on what to do. Only 15 s after the voice communication message, passengers started to move.

The delay time to start has also been studied through reports of fire victims. Although it is recognized that victims may have difficulty reporting accurately the delay time they took before starting to evacuate, there are interview techniques that can help to obtain acceptable estimates [11, 12]. In Australia, Brennan used such interview techniques to obtain detailed accounts of fire victims [13]. She studied a severe highrise office fire that started in a stack of polyurethane-

padded chairs stored on the 3rd level of a 14-storey building. The fire grew rapidly emitting a large quantity of smoke. The central fire alarm system never sounded. Victims reported becoming aware of the incident by seeing and smelling smoke or being warned by others. From the interviews it was estimated that the mean time to start evacuation was approximately 2 min 30 s.

Brennan also studied the occupants' behaviour during a highrise residential fire that occurred at night [14]. From interviews with victims it was estimated that occupants took around 10 min to start evacuation after hearing the fire alarm and seeing light smoke in the corridor. It should be noted that it is estimated that only half the occupants of that building actually evacuated during that fire.

Two highrise residential fires in Canada that resulted in 6 fatalities in stairwells in one case and one fatality in the suite of origin in the other case were studied [15, 16]. The highrise fire with 6 fatalities occurred at night in the wintertime. According to the occupant accounts the fire alarm was not audible in many of the apartments; these occupants learned about the fire from the warning of others. Victims estimated their time to start evacuation at 10 to 30 min for occupants who attempted to evacuate. In the second case study, all occupants heard the fire alarm since there was a sounder in every unit. Occupants waited for instructions from the voice communication system. Evacuees estimated that they took 5 min before starting to evacuate after receiving the evacuation order.

These different studies on the delay time to start show the marked difference in response time according to the type of warning obtained. The time to start will vary according to the information available. The fire alarm signal is probably the least reliable cue of a fire since there are a large number of false alarms, test alarms or prank alarms in some buildings that have reduced the credibility of this signal as an indication of a real fire [17]. Fire cues, such as a smell of burning or seeing smoke come forth have become very ambiguous, initiating investigation response from occupants more than evacuation movement. Obtaining a warning by others appears to be a better indication of an actual problem. Receiving a message through a voice communication system or directly by staff seem to be the signals that are taken most seriously by occupants indicating a requirement to promptly leave the area.

PROVIDING INFORMATION TO THE OCCUPANTS

It appears essential to develop means to reduce the time delay to start evacuation. The key strategy to reduce this delay time is to provide information as early as possible to the occupants.

In providing information, the first step should be the installation of a fire alarm signal emitting the Temporal-Three evacuation signal, as described in ISO 8201 [18]. This will help facilitate recognition of the fire alarm signal itself. This standard temporal pattern is now required in all new and refurbished buildings in Canada and the United States. It is expected that as other countries adopt this

standard for their fire alarm signal, the occupants will eventually rapidly recognise this signal as the evacuation signal.

Building occupants may hear and eventually recognize the fire alarm signal but may be so engrossed in an activity that they do not pay any attention to it. What is needed is to change the environment to switch their attention from their current activity to the emergency. The appropriate change will depend on the type of building and the type of occupancy.

In a shopping centre, an appropriate change of environment would be to turn off the background music. In a movie theatre, the projector should be stopped and the lights turned on. Similarly, in a discotheque or restaurant, the music should be stopped and full lighting should flood the space. This type of sudden and sharp change in atmosphere alerts occupants to the fact that something serious is happening and shifts their attention to the emergency. Protests from patrons will die down as complementary information is provided.

In large public buildings such as museums, department stores and airport terminals, occupants are very unlikely to take any action, at least initially when the alarm signal is activated. Social interactions tend to occur first: people will observe what others are doing and if no one is paying attention to the alarm, they will be reluctant to take any action that would make them appear out of place or over-reacting. To motivate response in such occupancies, further information should be provided to the occupant. Visitors generally feel it is their role to wait for instructions from staff or a figure of authority. They expect they will be told what to do if something truly serious is happening. The method of choice for instructing occupants of large public buildings is a voice communication system.

In the past, voice communicaton was rarely used to provide emergency information because of the false idea that occupants will panic if they are told that there is a fire. In fact, the opposite is true: being told the truth is more likely to trigger appropriate reaction, not dysfunctional behaviour. Research and studies of actual fires demonstrate that providing information through a voice communication system is one of the best ways to ensure immediate reaction by occupants as long as the messages are audible and intelligible. Contrary to some beliefs, occupants tend to immediately obey instructions received through voice communication systems [10, 16].

There should be no delay in using voice communication once an emergency has been identified. The message should describe the emergency and instruct occupants on the best course of action. On-site managers should be prepared to decide quickly whether to evacuate the premises or to direct occupants to a safe location within the building. Waiting for the fire department to arrive and assess the situation before instructing occupants is not a good idea, for two reasons. First, when firefighters arrive they expect all occupants to be in a safe location, allowing them to focus on controlling the fire instead of performing search and

rescue missions. Second, waiting the five to ten minutes it takes for firefighters to arrive could prove lethal: for example, the delay may eventually require occupants to move through smoke-filled areas in an attempt to reach safety [16].

Messages should be simple, direct and truthful. Attempting to downplay an emergency or using technical jargon to disguise the real situation could confuse people and prevent them from reacting appropriately. Instead, it is important to identify the problem in common terms such as “we suspect a fire” or “a fire has been detected.” Identifying the location is essential: occupants will wonder if they are at immediate risk and knowing were the fire is, will help them decide what to do. Finally, the message should clearly explain what is expected of the occupants: in some cases, it might be best for them to remain on location; in others, directing them through a specific route to a specific exit might be more appropriate.

Some buildings are equipped with a voice communication system that delivers recorded messages. Although such a system may save staff time, the use of recorded messages has proven ineffective and even dangerous. A field study demonstrated that such messages could not be precise enough to help occupants locate the nearest exit. During the evacuation of an underground station where the main escalator was blocked, occupants did not know where to go because the recorded message could not pinpoint the location of an alternative way out [10].

There are many advantages to live messages. For one, instructions can be updated as new information is obtained. Second, the tone of the message can convey the urgency of the situation. Finally, occupants are more receptive to live messages because they are more likely to consider the information to be genuine and reliable.

Since many buildings are now equipped with closed-circuit televisions (CCTVs) for security purposes, these can also be a valuable tool for delivering precise messages during an emergency. Strategically placed CCTVs allow the person behind the microphone to view conditions in different areas of the premises. Messages can then be tailored to suit crowd movement and the developing fire situation.

Occupants’ knowledge and assumptions regarding the development of a fire are often wrong. The literature is full of anecdotes about people not doing what they were expected to do or, worse, doing things that endangered their lives. If we expect occupants to do the right things during a fire emergency, they must be trained. The public should be educated about fire, how it can start, how it develops and what impact it has on people. Most fire-safety education programs are targeted toward children, but other groups are at risk as well, especially residents of old-age homes and the disabled.

In public buildings, such as airport terminals or sport centres, occupant training is not practical; for these, much of the responsibility for safety will rest with staff. Consequently, staff training is paramount. Occupants are very likely to look for staff members to obtain information; they are regarded as knowledgeable, they are expected to know the situation, the best course of action and the closest exit. Whether heard on a speaker or seen in uniform or wearing a name tag, staff are likely to be listened to. Staff training should include regular classroom sessions as well as evacuation drills. Drills are a valuable means for moving staff training into practice and for them to assess the application of the building's fire-safety plan. Feedback from staff and occupants after a drill helps identify issues needing improvement. An assessment is also advisable after false alarms and actual fires in order to identify deficiencies in the fire safety plan.

When dealing with large spaces or with large crowds, it is not practical to rely entirely on staff to direct occupants to safety, as the number of employees required might be very large. For such situations, it is more efficient to rely on a few well-trained staff members, the voice communication system and CCTVs.

EVACUATION MOVEMENT

When the fire alarm is activated, it should provide enough time for occupants to move to a safe location before conditions become dangerous. If the occupants do not start to move immediately, the time available for safe escape becomes shorter. To minimize the possibility of delay, information should be provided to the occupants to prompt movement. Movement can be prompted through a dramatic change in the environment as indicated earlier, through voice communication messages and through staff instructions. These actions should come into play as soon as possible after the alarm activation.

The calculation of movement is fairly simple. A number of authors have published on the subject. The SFPE Handbook is an excellent source of information on calculation of speed of movement [19]. It should be kept in mind that most equations and calculation methods do not take into account crowd composition and abilities [20], as well as the effect of fatigue, stress and movement under smoke conditions [21].

When considering occupants' evacuation movement, some dimensions should be considered carefully. Familiarity and experience with the building for example will have a major impact on occupants' choice of evacuation route. It has been observed during drill and actual fires that non-familiar occupants are more likely to attempt to exit by the way they entered the building even though an emergency exit might be closer to their location. This can be explained by the fact that occupants are very unlikely to be prepared to try a new unknown route during an emergency. Occupants never know if the emergency exit is safe, the route could be locked or blocked and it may lead to an unsafe location. In comparison, the way they came into the building is known by occupants and it is reassuring to go that way to exit during an emergency.

Another dimension rarely considered in the calculation of movement is the fact that occupants are prepared to move through smoke even though they know that smoke kills. The movement speed of occupants in a smoky environment can drop dramatically due to the difficulty on seeing and breathing. Movement in smoke should be absolutely avoided for its potential lethal effect. The reality is however, that occupants in fire often move though smoke which reduces their speed of movement. Movement calculations are usually over-optimistic compared to actual movement speed during fires since a number of dimensions interplay to reduce the speed of movement to leave the building.

SUMMARY

Although adequate fire safety systems are often installed in buildings, failure of these systems to work “as planned” is regularly observed when an actual fire occurs. Problems frequently arise during fire incidents because systems were put in place with false expectations regarding how occupants actually behave during fires. It has been observed regularly that occupants have a tendency to ignore the sound of the fire alarm in large public buildings such as shopping centres, museums or airports, continuing their normal activities. In office buildings, well designed fire doors have failed to fulfil their role because occupants have installed door stops to facilitate free movement in the everyday use of the building; thus in the event of a fire the doors stay open. Occupants of apartment buildings sometimes tampered with the fire alarm sounders to silence them, if they feel they have to respond to too many false alarms. Many of these problems could be foreseen if there was more attention given to human behaviour in fire.

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